CLAIMS

We Claim:

1. A catalyst composition comprising the contact product of a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound is selected from an *ansa*-metallocene having the following formula:

i) $(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from a fluorenyl and a cyclopentadienyl, a fluorenyl and an indenyl, or two fluorenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof; or

ii) *rac*-$(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from two indenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof;

wherein M^1 is selected from Ti, Zr, or Hf;

wherein (X^1) and (X^2) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^1) and (X^2); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^1) and the other end of which is bonded to (X^2); and

wherein (X^3); (X^4); each substituent on the substituted cyclopentadienyl, the substituted indenyl, and the substituted fluorenyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic

group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) the second metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^5)(X^6)(X^7)(X^8)M^2,$$

wherein M^2 is selected from Ti, Zr, or Hf;

wherein (X^5) and (X^6) are independently selected from a cyclopentadienyl or a substituted cyclopentadienyl;

wherein (X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^5) and (X^6); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); and

wherein when (X^5) or (X^6) is a substituted cyclopentadienyl, the substituted cyclopentadienyl is substituted with up to four substituents, in addition to the bridging group;

wherein (X^7); (X^8); each substituent on the substituted cyclopentadienyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen; and

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion.

2. The catalyst composition of Claim 1, wherein the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

3. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion, wherein:

the solid oxide is selected from silica, alumina, silica-alumina, aluminum phosphate, heteropolytungstates, titania, zirconia, magnesia, boria, zinc oxide, mixed oxides thereof, or mixtures thereof; and

the electron-withdrawing anion is selected from fluoride, chloride, bromide, phosphate, triflate, bisulfate, sulfate, or any combination thereof.

4. The catalyst composition of Claim 1, wherein:

a) the first metallocene compound is selected from an *ansa*-metallocene having the following formula:

i) $(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from a fluorenyl and a cyclopentadienyl, a fluorenyl and an indenyl, or two fluorenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof; or

ii) *rac*-$(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from two indenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof;

wherein M^1 is selected from Zr or Hf;

wherein (X^1) and (X^2) are connected by a bridging group selected from $>CR^1_2$, $>SiR^1_2$, or $-CR^1_2CR^1_2-$, wherein R^1 in each instance is independently selected from a linear, branched, substituted, or unsubstituted hydrocarbyl group, any one of which having from 1 to about 20 carbon atoms; or hydrogen;

wherein any substituent on (X^1), (X^2), or R^1 is independently selected from a hydrocarbyl group, an oxygen group, a sulfur group, a nitrogen group, a phosphorus

group, an inorganic group, an organometallic group, having from 1 to about 20 carbon atoms; a halide; or hydrogen; and

wherein (X^3) and (X^4) are independently selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and

b) the second metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^5)(X^6)(X^7)(X^8)Zr,$$

wherein (X^5) and (X^6) are independently selected from a cyclopentadienyl or a substituted cyclopentadienyl;

wherein (X^5) and (X^6) are connected by a bridging group selected from $>CR^2_2$, $>SiR^2_2$, or $-CR^2_2CR^2_2-$, wherein R^2 in each instance is independently selected from a linear, branched, substituted, or unsubstituted hydrocarbyl group, any one of which having from 1 to about 20 carbon atoms; or hydrogen;

wherein when (X^5) or (X^6) is a substituted cyclopentadienyl, the substituted cyclopentadienyl is substituted with up to four substituents, in addition to the bridging group;

wherein any substituent on (X^5), (X^6), or R^2 is independently selected from a hydrocarbyl group, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an inorganic group, an organometallic group, having from 1 to about 20 carbon atoms; a halide; or hydrogen; and

wherein (X^7) and (X^8) are independently selected from alkoxide, aryloxide, or amide having from 1 to about 20 carbon atoms, halide, or hydride.

5. The catalyst composition of Claim 1, wherein the first metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^1)(X^2)(X^3)(X^4)M^1,$$

wherein M^1 is selected from Zr or Hf;

wherein (X^1) and (X^2) are jointly selected from a fluorenyl and a cyclopentadienyl or two fluorenyls, any one of which can be substituted or unsubstituted;

wherein (X^1) and (X^2) are connected by a bridging group selected from $>CR^1_2$, $>SiR^1_2$, or $-CR^1_2CR^1_2-$, wherein R^1 in each instance is independently selected from a

linear, branched, substituted, or unsubstituted hydrocarbyl group, any one of which having from 1 to about 20 carbon atoms; halide; or hydrogen;

wherein any substituent on (X^1), (X^2), or R^1 is independently selected from a hydrocarbyl group, an oxygen group, a sulfur group, a nitrogen group, any one of which having from 1 to about 20 carbon atoms; or hydrogen; and

wherein (X^3) and (X^4) are independently selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride.

6. The catalyst composition of Claim 1, wherein the first metallocene compound is an *ansa*-metallocene having the following formula:

$$rac\text{-}(X^1)(X^2)(X^3)(X^4)Zr;$$

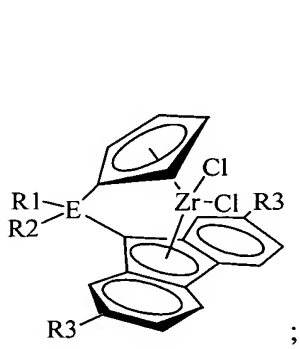
wherein (X^1) and (X^2) are jointly selected from two indenyls, any one of which can be substituted or unsubstituted;

wherein (X^1) and (X^2) are connected by a bridging group selected from $>CR^1_2$, $>SiR^1_2$, or $-CR^1_2CR^1_2-$, wherein R^1 in each instance is independently selected from a linear, branched, substituted, or unsubstituted hydrocarbyl group, any one of which having from 1 to about 20 carbon atoms; or hydrogen;

wherein any substituent on (X^1), (X^2), or R^1 is independently selected from a hydrocarbyl group, an oxygen group, a sulfur group, a nitrogen group, any one of which having from 1 to about 20 carbon atoms; or hydrogen; and

wherein (X^3) and (X^4) are independently selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride.

7. The catalyst composition of Claim 1, wherein the first metallocene compound is selected from a compound of the following formula:



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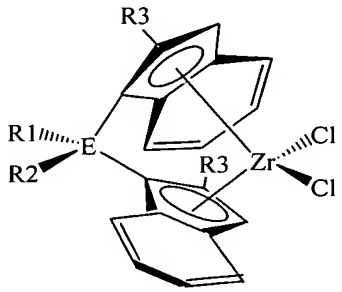

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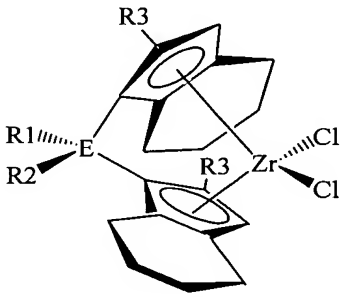

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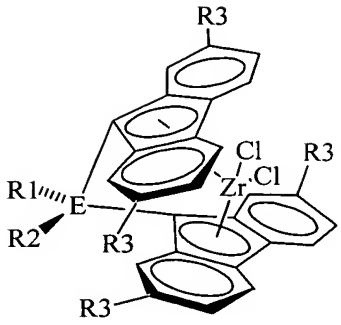
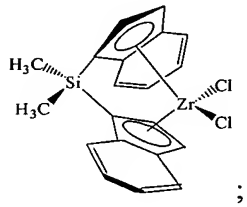


; or any combination thereof;

wherein E is selected from C, Si, Ge, or Sn; and wherein R1, R2, and R3, in each instance, is independently selected from H or a hydrocarbyl group having from 1 to about 20 carbon atoms.

8. The catalyst composition of Claim 1, wherein the first metallocene compound is selected from:



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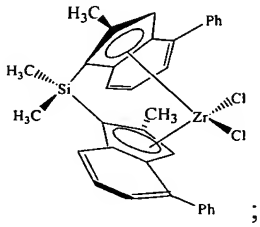

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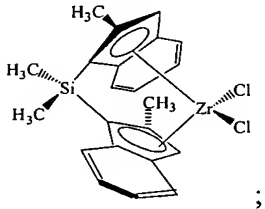

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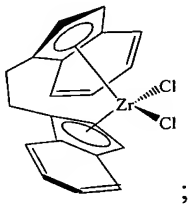

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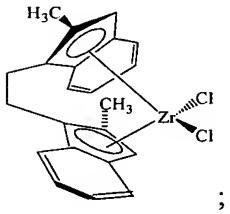

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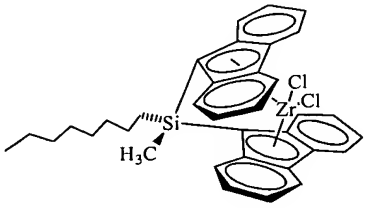

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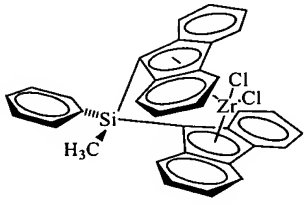

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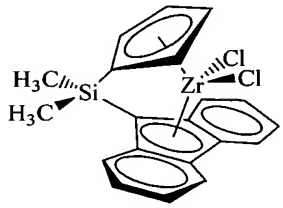

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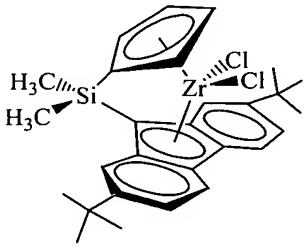

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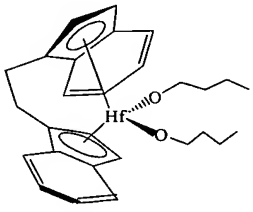

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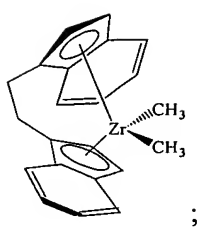

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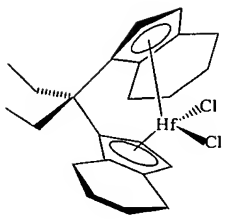

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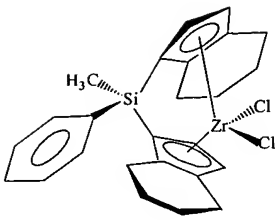

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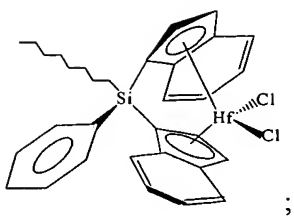

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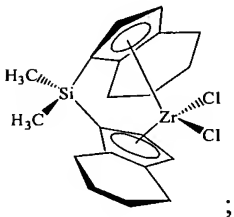

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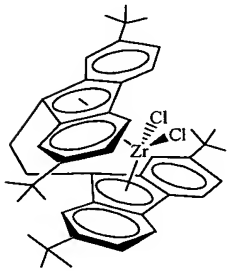


; or any combination thereof.

9. The catalyst composition of Claim 1, wherein the first metallocene compound is selected from:

2-(η^5-cyclopentadienyl)-2-(η^5-fluoren-9-yl)hex-5-ene zirconium(IV) dichloride, [(η^5-C_5H_4)CCH_3(CH_2CH_2CH=CH_2)(η^5-9-$C_{13}H_9$)]$ZrCl_2$;

2-(η^5-cyclopentadienyl)-2-(η^5-2,7-di-*tert*-butylfluoren-9-yl)hex-5-ene zirconium(IV) dichloride, [(η^5-C_5H_4)CCH_3(CH_2CH_2CH=CH_2)(η^5-9-$C_{13}H_7$-2,7-(^{t}Bu$_2$)]$ZrCl_2$;

2-(η^5-cyclopentadienyl)-2-(η^5-fluoren-9-yl)hept-6-ene zirconium(IV) dichloride, [(η^5-C_5H_4)CCH_3($CH_2CH_2CH_2CH$=CH_2)(η^5-9-$C_{13}H_9$)]$ZrCl_2$;

2-(η^5-cyclopentadienyl)-2-(η^5-2,7-di-*tert*-butylfluoren-9-yl)hept-6-ene zirconium(IV) dichloride, [(η^5-C_5H_4)CCH_3($CH_2CH_2CH_2CH$=CH_2)(η^5-9-$C_{13}H_7$-2,7-^{t}Bu$_2$)]$ZrCl_2$;

1-(η^5-cyclopentadienyl)-1-(η^5-fluoren-9-yl)-1-phenylpent-4-ene zirconium(IV) dichloride, [(η^5-C_5H_4)C(C_6H_5)(CH_2CH_2CH=CH_2)(η^5-9-$C_{13}H_9$)]$ZrCl_2$;

1-(η^5-cyclopentadienyl)-1-(η^5-2,7-di-*tert*-butyl fluoren-9-yl)-1-phenylpent-4-ene zirconium(IV) dichloride, [(η^5-C_5H_4)C(C_6H_5)(CH_2CH_2CH=CH_2)(η^5-9-$C_{13}H_7$-2,7-^{t}Bu$_2$)]$ZrCl_2$;

1-(η^5-cyclopentadienyl)-1-(η^5-fluoren-9-yl)-1-phenylhex-5-ene zirconium(IV) dichloride, [(η^5-C_5H_4)C(C_6H_5)($CH_2CH_2CH_2CH$=CH_2)(η^5-9-$C_{13}H_9$)]$ZrCl_2$;

1-(η^5-cyclopentadienyl)-1-(η^5-2,7-di-*tert*-butylfluoren-9-yl)-1-phenylhex-5-ene zirconium(IV) dichloride, [(η^5-C_5H_4)C(C_6H_5)($CH_2CH_2CH_2CH{=}CH_2$)(η^5-9-$C_{13}H_7$-2,7-$^tBu_2$)]$ZrCl_2$;

or any combination thereof.

10. The catalyst composition of Claim 1, wherein the second metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^5)(X^6)(X^7)(X^8)Zr,$$

wherein (X^5) and (X^6) are independently selected from a cyclopentadienyl or a substituted cyclopentadienyl;

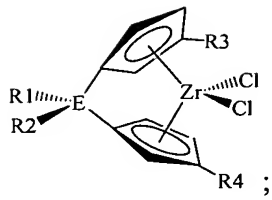
wherein (X^5) and (X^6) are connected by a bridging group selected from $>CR^2_2$, $>SiR^2_2$, or $-CR^2_2CR^2_2-$, wherein R^2 in each instance is independently selected from a linear, branched, substituted, or unsubstituted hydrocarbyl group, any one of which having from 1 to about 20 carbon atoms; or hydrogen;

wherein when (X^5) or (X^6) is a substituted cyclopentadienyl, the substituted cyclopentadienyl is substituted with up to four substituents, in addition to the bridging group;

wherein any substituent on (X^5), (X^6), or R^2 is independently selected from a hydrocarbyl group, an oxygen group, a sulfur group, a nitrogen group, any one of which having from 1 to about 20 carbon atoms; or hydrogen; and

wherein (X^7) and (X^8) are independently selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride.

11. The catalyst composition of Claim 1, wherein the second metallocene compound is selected from a compound of the following formula:



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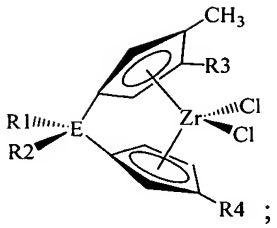

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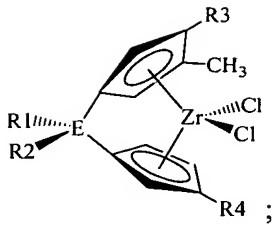

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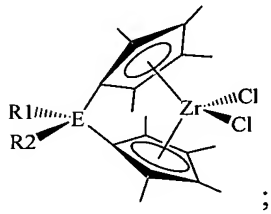
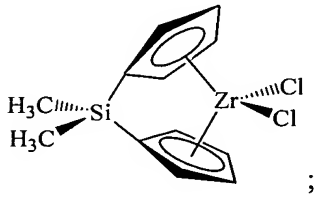


; or any combination thereof;

wherein E is selected from C, Si, Ge, or Sn; and wherein R1, R2, R3, and R4, in each instance, is independently selected from H or a hydrocarbyl group having from 1 to about 20 carbon atoms.

12. The catalyst composition of Claim 1, wherein the second metallocene compound is selected from:



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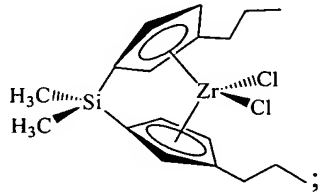

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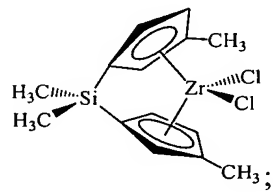

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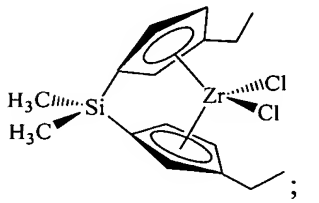

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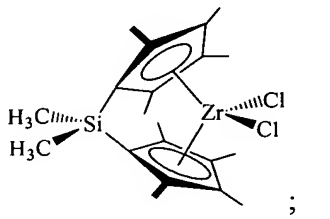

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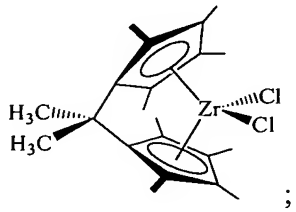

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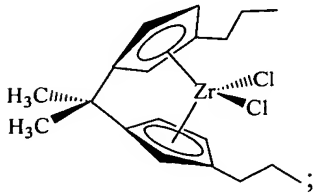

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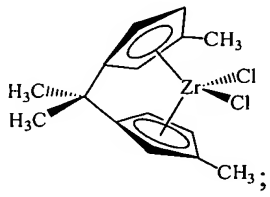

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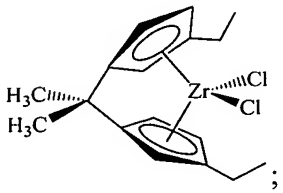

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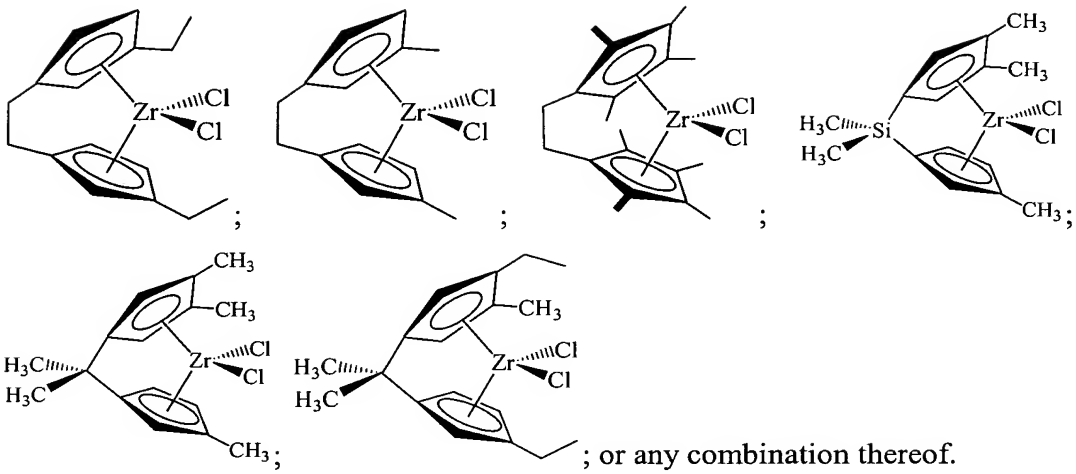


; or any combination thereof.

13. The catalyst composition of Claim 1, wherein:

a) the first metallocene compound is selected from *rac*-$C_2H_4(\eta^5\text{-Ind})_2ZrCl_2$, *rac*-$Me_2Si(\eta^5\text{-Ind})_2ZrCl_2$, $Me(octyl)Si(\eta^5\text{-Flu})_2ZrCl_2$, *rac*-$Me_2Si(\eta^5\text{-2-Me-4-PhInd})_2ZrCl_2$, *rac*-$C_2H_4(\eta^5\text{-2-MeInd})_2ZrCl_2$, $Me(Ph)Si(\eta^5\text{-Flu})_2ZrCl_2$, or any combination thereof;

b) the second metallocene compound is selected from *rac*-$Me_2Si(\eta^5\text{-3-n-PrCp})_2ZrCl_2$, $Me_2Si(\eta^5\text{-Me}_4\text{Cp})_2ZrCl_2$, $Me_2Si(\eta^5\text{-Cp})_2ZrCl_2$, or any combination thereof;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, sulfated alumina, fluorided silica-alumina, or any combination thereof; and

d) the organoaluminum compound is selected from triethylaluminum or triisobutylaluminum.

14. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, bromided alumina, sulfated alumina, fluorided silica-alumina, chlorided silica-alumina, bromided silica-alumina, sulfated silica-alumina, fluorided silica-zirconia, chlorided silica-zirconia, bromided silica-zirconia, sulfated silica-zirconia, or any combination thereof.

15. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide further comprises a metal or metal ion selected from zinc, nickel, vanadium, silver, copper, gallium, tin, tungsten, molybdenum, or any combination thereof.

16. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide further comprises a metal or metal ion and is selected from zinc-impregnated chlorided alumina, zinc-impregnated fluorided alumina, zinc-impregnated chlorided silica-alumina, zinc-impregnated fluorided silica-alumina, zinc-impregnated sulfated alumina, or any combination thereof.

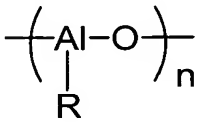
17. The catalyst composition of Claim 1, wherein the weight ratio of the organoalumium compound to the chemically-treated solid oxide is from about 10:1 to about 1:1,000.

18. The catalyst composition of Claim 1, wherein the organoaluminum compound is selected from trimethylaluminum, triethylaluminum, tri-n-propylaluminum, diethylaluminum ethoxide, tri-n-butylaluminum, disobutylaluminum hydride, triisobutylaluminum, diethylaluminum chloride, or any combination thereof.

19. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one aluminoxane, at least one organozinc compound, at least one organoboron compound, at least one ionizing ionic compound, or any combination thereof.

20. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one aluminoxane compound, wherein the aluminoxane comprises

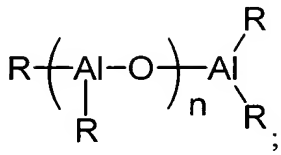
a cyclic aluminoxane having the formula:



; wherein

R is a linear or branched alkyl having from 1 to 10 carbon atoms, and n is an integer from 3 to about 10;

a linear aluminoxane having the formula:


; wherein

R is a linear or branched alkyl having from 1 to 10 carbon atoms, and n is an integer from 1 to about 50;

a cage aluminoxane having the formula $R^t_{5m+\alpha}R^b_{m-\alpha}Al_{4m}O_{3m}$, wherein m is 3 or 4 and α is = $n_{Al(3)}$ - $n_{O(2)}$ + $n_{O(4)}$; wherein $n_{Al(3)}$ is the number of three coordinate aluminum atoms, $n_{O(2)}$ is the number of two coordinate oxygen atoms, $n_{O(4)}$ is the number of 4 coordinate oxygen atoms, R^t represents a terminal alkyl group, and R^b represents a bridging alkyl group; wherein R is a linear or branched alkyl having from 1 to 10 carbon atoms; or

any combination thereof.

21. The catalyst composition of Claim 20, wherein the molar ratio of the aluminum in the aluminoxane to the combined first metallocene compound and second metallocene compound in the catalyst composition is from about 1:10 to about 100,000:1.

22. The catalyst composition of Claim 20, wherein the aluminoxane compound is selected from methylaluminoxane, ethylaluminoxane, n-propylaluminoxane, iso-propylaluminoxane, n-butylaluminoxane, t-butylaluminoxane, sec-butylaluminoxane, iso-butylaluminoxane, 1-pentylaluminoxane, 2-pentylaluminoxane, 3-pentylaluminoxane, iso-pentylaluminoxane, neopentylaluminoxane, or a combination thereof.

23. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one organozinc compound, wherein the organozinc compound has the following formula:

$$Zn(X^{13})(X^{14});$$

wherein (X^{13}) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{14}) is selected from a hydrocarbyl, an alkoxide or an aryloxide having from 1 to about 20 carbon atoms, halide, or hydride;

24. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one organozinc compound, wherein the organozinc compound is selected from dimethylzinc, diethylzinc, dipropylzinc, dibutylzinc, dineopentylzinc, di(trimethylsilylmethyl)zinc, or any combination thereof.

25. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one organoboron compound, wherein the organoboron compound is selected from tris(pentafluorophenyl)boron, tris[3,5-bis(trifluoromethyl)phenyl]boron, *N,N*-dimethylanilinium tetrakis(pentafluorophenyl)borate, triphenylcarbenium tetrakis(pentafluorophenyl)borate, lithium tetrakis(pentafluorophenyl)borate, *N,N*-dimethylanilinium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, triphenylcarbenium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, or a combination thereof.

26. The catalyst composition of Claim 25, wherein the molar ratio of the organoboron compound to the combined first metallocene compound and second metallocene compound in the catalyst composition is from about 0.1:1 to about 10:1.

27. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one ionizing ionic compound, wherein the ionizing ionic compound is selected from tri(n-butyl)ammonium tetrakis(p-tolyl)borate, tri(n-butyl)-ammonium tetrakis(m-tolyl)borate, tri(n-butyl)ammonium tetrakis(2,4-dimethyl)-borate, tri(n-butyl)ammonium tetrakis(3,5-dimethylphenyl)borate, tri(n-butyl)-ammonium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, tri(n-butyl)ammonium tetrakis(pentafluorophenyl)borate, N,N-dimethylanilinium tetrakis(p-tolyl)borate, N,N-dimethylanilinium tetrakis(m-tolyl)borate, N,N-dimethylanilinium tetrakis(2,4-dimethylphenyl)borate, N,N-dimethylanilinium tetrakis(3,5-dimethylphenyl)borate, N,N-dimethylanilinium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, N,N-dimethylanilinium tetrakis(pentafluorophenyl)borate, triphenylcarbenium tetrakis(p-

tolyl)borate, triphenylcarbenium tetrakis(m-tolyl)borate, triphenylcarbenium tetrakis(2,4-dimethylphenyl)borate, triphenylcarbenium tetrakis(3,5-dimethylphenyl)borate, triphenylcarbenium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, triphenylcarbenium tetrakis(pentafluorophenyl)borate, tropylium tetrakis(p-tolyl)borate, tropylium tetrakis(m-tolyl)borate, tropylium tetrakis(2,4-dimethylphenyl)borate, tropylium tetrakis(3,5-dimethylphenyl)borate, tropylium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, tropylium tetrakis(pentafluorophenyl)borate, lithium tetrakis(pentafluorophenyl)borate, lithium tetrakis(phenyl)borate, lithium tetrakis(p-tolyl)borate, lithium tetrakis(m-tolyl)borate, lithium tetrakis(2,4-dimethylphenyl)borate, lithium tetrakis(3,5-dimethylphenyl)borate, lithium tetrafluoroborate, sodium tetrakis(pentafluorophenyl)borate, sodium tetrakis(phenyl) borate, sodium tetrakis(p-tolyl)borate, sodium tetrakis(m-tolyl)borate, sodium tetrakis(2,4-dimethylphenyl)borate, sodium tetrakis-(3,5-dimethylphenyl)borate, sodium tetrafluoroborate, potassium tetrakis-(pentafluorophenyl)borate, potassium tetrakis(phenyl)borate, potassium tetrakis(p-tolyl)borate, potassium tetrakis(m-tolyl)borate, potassium tetrakis(2,4-dimethylphenyl)borate, potassium tetrakis(3,5-dimethylphenyl)borate, potassium tetrafluoroborate, tri(n-butyl)ammonium tetrakis(p-tolyl)aluminate, tri(n-butyl)ammonium tetrakis(m-tolyl)aluminate, tri(n-butyl)ammonium tetrakis(2,4-dimethyl)aluminate, tri(n-butyl)ammonium tetrakis(3,5-dimethylphenyl)aluminate, tri(n-butyl)ammonium tetrakis(pentafluorophenyl)aluminate, N,N-dimethylanilinium tetrakis(p-tolyl)-aluminate, N,N-dimethylanilinium tetrakis(m-tolyl)aluminate, N,N-dimethylanilinium tetrakis(2,4-dimethylphenyl)aluminate, N,N-dimethylanilinium tetrakis(3,5-dimethylphenyl)aluminate, N,N-dimethylanilinium tetrakis (pentafluorophenyl)aluminate, triphenylcarbenium tetrakis(p-tolyl)aluminate, triphenylcarbenium tetrakis(m-tolyl)-aluminate, triphenylcarbenium tetrakis(2,4-dimethylphenyl)aluminate, triphenylcarbenium tetrakis(3,5-dimethylphenyl)aluminate, triphenylcarbenium tetrakis-(pentafluorophenyl)aluminate, tropylium tetrakis(p-tolyl)aluminate, tropylium tetrakis(m-tolyl)aluminate, tropylium tetrakis(2,4-dimethylphenyl)aluminate, tropylium tetrakis(3,5-dimethylphenyl)aluminate, tropylium tetrakis(pentafluorophenyl)aluminate, lithium tetrakis(pentafluorophenyl)aluminate, lithium tetrakis-(phenyl)aluminate, lithium tetrakis(p-tolyl)aluminate, lithium tetrakis(m-

tolyl)aluminate, lithium tetrakis(2,4-dimethylphenyl)aluminate, lithium tetrakis(3,5-dimethylphenyl)aluminate, lithium tetrafluoroaluminate, sodium tetrakis(pentafluorophenyl)aluminate, sodium tetrakis(phenyl)aluminate, sodium tetrakis(p-tolyl)aluminate, sodium tetrakis(m-tolyl)aluminate, sodium tetrakis(2,4-dimethylphenyl)aluminate, sodium tetrakis(3,5-dimethylphenyl)aluminate, sodium tetrafluoroaluminate, potassium tetrakis(pentafluorophenyl)aluminate, potassium tetrakis(phenyl)aluminate, potassium tetrakis(p-tolyl)aluminate, potassium tetrakis(m-tolyl)aluminate, potassium tetrakis(2,4-dimethylphenyl)aluminate, potassium tetrakis (3,5-dimethylphenyl)aluminate, potassium tetrafluoroaluminate, or any combination thereof.

28. A composition of matter comprising a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound is selected from an *ansa*-metallocene having the following formula:

i) $(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from a fluorenyl and a cyclopentadienyl, a fluorenyl and an indenyl, or two fluorenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof; or

ii) *rac*-$(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from two indenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof;

wherein M^1 is selected from Ti, Zr, or Hf;

wherein (X^1) and (X^2) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^1) and (X^2); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^1) and the other end of which is bonded to (X^2); and

wherein (X^3); (X^4); each substituent on the substituted cyclopentadienyl, the substituted indenyl, and the substituted fluorenyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) the second metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^5)(X^6)(X^7)(X^8)M^2,$$

wherein M^2 is selected from Ti, Zr, or Hf;

wherein (X^5) and (X^6) are independently selected from a cyclopentadienyl or a substituted cyclopentadienyl;

wherein (X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^5) and (X^6); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); and

wherein when (X^5) or (X^6) is a substituted cyclopentadienyl, the substituted cyclopentadienyl is substituted with up to four substituents, in addition to the bridging group;

wherein (X^7); (X^8); each substituent on the substituted cyclopentadienyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen; and

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

29. A method of making a catalyst composition comprising contacting a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound is selected from an *ansa*-metallocene having the following formula:

i) $(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from a fluorenyl and a cyclopentadienyl, a fluorenyl and an indenyl, or two fluorenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof; or

ii) *rac*-$(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from two indenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof;

wherein M^1 is selected from Ti, Zr, or Hf;

wherein (X^1) and (X^2) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^1) and (X^2); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^1) and the other end of which is bonded to (X^2); and

wherein (X^3); (X^4); each substituent on the substituted cyclopentadienyl, the substituted indenyl, and the substituted fluorenyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an

aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) the second metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^5)(X^6)(X^7)(X^8)M^2,$$

wherein M^2 is selected from Ti, Zr, or Hf;

wherein (X^5) and (X^6) are independently selected from a cyclopentadienyl or a substituted cyclopentadienyl;

wherein (X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^5) and (X^6); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); and

wherein when (X^5) or (X^6) is a substituted cyclopentadienyl, the substituted cyclopentadienyl is substituted with up to four substituents, in addition to the bridging group;

wherein (X^7); (X^8); each substituent on the substituted cyclopentadienyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen; and

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

30. A method of polymerizing olefins comprising contacting at least one type of olefin monomer with a catalyst composition under polymerization conditions, wherein the catalyst composition comprises the contact product of a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound is selected from an *ansa*-metallocene having the following formula:

i) $(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from a fluorenyl and a cyclopentadienyl, a fluorenyl and an indenyl, or two fluorenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof; or

ii) *rac*-$(X^1)(X^2)(X^3)(X^4)M^1$,

wherein (X^1) and (X^2) are jointly selected from two indenyls, any one of which can be substituted, unsubstituted, partially saturated, or any combination thereof;

wherein M^1 is selected from Ti, Zr, or Hf;

wherein (X^1) and (X^2) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^1) and (X^2); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^1) and the other end of which is bonded to (X^2); and

wherein (X^3); (X^4); each substituent on the substituted cyclopentadienyl, the substituted indenyl, and the substituted fluorenyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and

cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) the second metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^5)(X^6)(X^7)(X^8)M^2,$$

wherein M^2 is selected from Ti, Zr, or Hf;

wherein (X^5) and (X^6) are independently selected from a cyclopentadienyl or a substituted cyclopentadienyl;

wherein (X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising:

i) one atom selected from carbon, silicon, germanium, or tin, bonded to both (X^5) and (X^6); or

ii) two contiguous carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); and

wherein when (X^5) or (X^6) is a substituted cyclopentadienyl, the substituted cyclopentadienyl is substituted with up to four substituents, in addition to the bridging group;

wherein (X^7); (X^8); each substituent on the substituted cyclopentadienyl; and each substituent on the substituted bridging group is independently selected from a hydrocarbyl group, an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, having from 1 to about 20 carbon atoms; a halide; or hydrogen; and

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

31. A polymer of ethylene, characterized by a melt index from about 3 to about 30 g/min; a density from about 0.915 to about 0.945 g/cm^3; a flow activation energy E_a from about 35 to about 45 kJ/mol; a polydispersity index (M_w/M_n) from about 3 to about 15; a M_z from about 300 to about 1,500 kg/mol; a M_w molecular weight from about 70 to about 200 kg/mol; and a number of Long Chain Branches per 1,000 carbon atoms (LCB/1000 carbon atoms) from about 0.02 to about 0.3, in the M_w molecular weight range of about 100 to about 1,000 kg/mol.

32. The polymer of Claim 31, wherein the melt index is from about 5 to about 20 g/min; the density is from about 0.915 to about 0.935 g/cm^3; the flow activation energy E_a is from about 37 to about 43 kJ/mol; the polydispersity index (M_w/M_n) is from about 4 to about 12; the M_z is from about 400 to about 1,200 kg/mol; the M_w molecular weight is from about 75 to about 150 kg/mol; and the number of Long Chain Branches per 1,000 carbon atoms (LCB/1000 carbon atoms) is from about 0.02 to about 0.25, in the M_w molecular weight range from about 100 to about 1,000 kg/mol.

33. The polymer of Claim 31, wherein the melt index is from about 7 to about 15 g/min; the density is from about 0.916 to about 0.930 g/cm^3; the flow activation energy E_a is from about 38 to about 42 kJ/mol; the polydispersity index (M_w/M_n) is from about 5 to about 10; the M_z is from about 500 to about 1,100 kg/mol; the M_w molecular weight is from about 80 to about 130 kg/mol; and the number of Long Chain Branches per 1,000 carbon atoms (LCB/1000 carbon atoms) is from about 0.02 to about 0.18, in the M_w molecular weight range from about 100 to about 1,000 kg/mol.

34. The polymer of Claim 31, wherein the polymer is further characterized by a Recoverable Shear Parameter x 1E3 (RSP) at 190 °C and 0.03 rad/s frequency from about 20 to about 500.

35. The polymer of Claim 31, wherein the polymer is further characterized by a Recoverable Shear Parameter x 1E3 (RSP) at 190 C and 0.03 rad/s frequency from about 80 to about 475.

36. The polymer of Claim 31, wherein the polymer is further characterized by a Recoverable Shear Parameter x 1E3 (RSP) at 190 C and 0.03 rad/s frequency from about 175 to about 450.

37. The polymer of Claim 31, wherein the polymer is further characterized by a neck-in at 300 ft/min line speed from about 3 to about 8 in/side.

38. The polymer of Claim 31, wherein the polymer is further characterized by a neck-in at 300 ft/min line speed from about 3 to about 6 in/side.

39. The polymer of Claim 31, wherein the polymer is further characterized by a neck-in at 300 ft/min line speed from about 3 to about 4.5 in/side.

40. The polymer of Claim 31, wherein the polymer is further characterized by a neck-in at 900 ft/min line speed from about 3 to about 8 in/side.

41. The polymer of Claim 31, wherein the polymer is further characterized by a neck-in at 900 ft/min line speed from about 3 to about 6 in/side.

42. The polymer of Claim 31, wherein the polymer is further characterized by a neck-in at 900 ft/min line speed from about 3 to about 4.5 in/side.

43. The polymer of Claim 31, wherein the polymer is further characterized by an extruder head pressure at 200 lb/hr extrusion rate from about 500 to about 2000 psi.

44. The polymer of Claim 31, wherein the polymer is further characterized by an extruder head pressure at 200 lb/hr extrusion rate from about 600 to about 1500 psi.

45. The polymer of Claim 31, wherein the polymer is further characterized by an extruder head pressure at 200 lb/hr extrusion rate from about 700 to about 1300 psi.

46. The polymer of Claim 31, wherein the polymer is further characterized by an extruder motor load at 200 lb/hr extrusion rate from about 40 to about 120 amps.

47. The polymer of Claim 31, wherein the polymer is further characterized by an extruder motor load at 200 lb/hr extrusion rate from about 50 to about 100 amps.

48. The polymer of Claim 31, wherein the polymer is further characterized by an extruder motor load at 200 lb/hr extrusion rate from about 60 to about 90 amps.

49. The polymer of Claim 31, wherein the polymer is further characterized by an Elmendorf MD tear resistance greater than or equal to about 2.1 g/lb/ream.

50. The polymer of Claim 31, wherein the polymer is further characterized by an Elmendorf TD tear resistance greater than or equal to about 2.9 g/lb/ream.

51. The polymer of Claim 31, wherein the polymer is further characterized by a Spencer impact strength greater than or equal to about 0.010 g/lb/ream.

52. The polymer of Claim 31, wherein the polymer is further characterized by a burst adhesion strength greater than or equal to about 95%.

53. The polymer of Claim 31, wherein the polymer is further characterized by a hot tack initiation temperature at which hot tack strength of 1N/25 mm strength is developed less than or equal to about 110°C.

54. The polymer of Claim 31, wherein the polymer is further characterized by a hot tack initiation temperature at which hot tack strength of 1N/25 mm strength is developed less than or equal to about 120°C.

55. The polymer of Claim 31, wherein the polymer is further characterized by an ultimate seal strength greater than or equal to about 3.5 lbf/in.

56. An article comprising the polymer of Claim 31.

57. An article comprising the polymer of Claim 31, wherein the article is selected from a container, a utensil, a film, a film product, a drum, a fuel tank, a pipe, a geomembranes, or a liner.